the storm reaches here and there will be quite a blow outward from the storm. This will soon be over, and then the wind becomes again easterly before the shower is over, and quite likely there will be a further series of showers. The same may be said of our winter snowstorms. Most of these move with the surface wind blowing at an angle of 135° to 180° with the movement of the cirrus, the cirro-stratus, and the attendant pallium haze. Our heaviest snowstorms move from the southwest attended by east to southeast winds.

PENETRATION OF SNOW BY BULLETS.

According to the French journal Cosmos, Vol. XXX, p. 386—

The officers of the 139th regiment of French infantry, in garrison at Aurillac, made some experiments in February, 1895, on thee ffect of shooting rifle balls into the snow from the Lebel rifle, and arrived at some very unexpected results. Heaps of snow varying in depths of from 1 to 2 meters were raised on the shooting grounds at Ombrado and Buis, near Aurillac, and the soldiers fired into them from a distance of 50 meters (164 feet). The Lebel ball only penetrated to a depth of 1.75 meters (5.7 feet). The cause of this phenomenon has not, as yet, been discovered. It is suggested, however, that by reason of its great velocity and rotation the ball attracts to itself an increasing mass of ice that finally destroys its power of penetration.

The above paragraph suggests an exceedingly interesting subject for careful experimental investigation. Will solid ice act as effectually as snow in stopping a rifle ball? Does hard packed snow resist the ball better than light drifted snow? Does the ball really gather about itself a large mass of snow-ice, or is the accumulation mostly in the rear and following after the ball?

ANCIENT CLIMATES NEAR CHICAGO.

The discovery of clearly-defined ancient lake beaches and layers of driftwood long since buried under the sand at the southern end of Lake Michigan has led Mr. Ossian Guthrie to compile a short account of this subject, from which we make the following brief extracts:

Nearly parallel with the shores of Lake Michigan and from half to three-fourths of a mile to the west of it is the beach of an ancient lake sloping to the west. The surface of this lake was about 12 feet above the present level of Lake Michigan, and on its eastern shore are buried the trunks and fragments of an ancient forest. * * * In 1871 the trunk of an immense white oak tree was found at the bottom of a trench when excavating for the main sewer in Michigan avenue south of Thirty-fourth street. In 1881 the trunk of an oak tree was found several feet below the ground at the corner of Lincoln and Belden avenues. In the same year the trunk of a white oak, stripped of its branches, without root or stump, 60 feet long and 2 feet in diameter, was found while excavating for a sewer in Forty-eighth street near Prairie avenue. In 1885, at the corner of Thirty-fourth street and Indiana avenue, the trunk of a large white oak was found, the under side of which had been flattened and cut away almost to the center, but there was no evidence of the work of man. In 1888, and near the location of the find of 1871, Mr. Guthrie discovered the bed of an ancient lake, completely covered with driftwood. During 1895, at Thirty-ninth street and Forest avenue, a large white oak trunk was found 11 feet below the surface. At Thirty-eighth street and Indiana avenue, 8 feet below the surface, a space 110 feet by 160 was completely excavated, and the general slope of the beach of the ancient lake could be determined; but below this first beach there was found an older beach, and it is possible that others are still below that.

During the Glacial epoch the basin of Lake Michigan was filled and covered to a great depth with ice in the form that constitutes a glacier. When the ice melted away at the southern end of the lake the glacier was still firm enough to choke up the north end of Lake Michigan, and the melted water constituted a lake whose level was probably 50 feet above the present level, as is proven by the remnants of the old beach line still to be found in various parts of the country. The many varieties of wood—elm, willow, white oak, butternut, and black walnut—are found here in promiscuous confusion, seeming to preclude the possibility that they grew where they are buried. The flattened and sand-rubbed surfaces of some of these trunks show that they have been drifting about and dragging and rubbing their sunken portions upon the sandy bed of the ancient lake.

During the Glacial period the Des Plaines River was entirely tributary to the Mississippi River, but at the close of the period it was entirely tributary to Lake Michigan. After awhile a sandbar was formed, by reason of which the Des Plaines became again tributary to the Mississippi; but subsequently the bar was broken through, and it flowed into Lake Michigan through the new channel, or what is now the south branch. Finally came the present condition, in which the river is mainly tributary to the Mississippi. All these changes have been the result of the action of ice and water, rain and wind. The heavy north winds built the 5 miles of sandy plains in the Calumet region, by reason of which the southern end of the great inland lake was filled in. If these processes at the south end of Lake Michigan be traced back to their connection with the changes going on at Niagara Falls, they give us six or eight thousand years as the approximate interval that must have elapsed since the disappearance of the Glacial ice in Lake Michigan. We infer that at that time the climate was not so greatly different from that which now prevails and that the same varieties of timber that are growing now could also flourish then.

STORM WAVE AT SAUSALITO.

On Monday, November 11, the automatic tide gauge maintained by the U. S. Coast and Geodetic Survey at Sausalito, near San Francisco, recorded an unusual series of rapid fluctuations. These began about 8.20 a. m., and continued for eighteen hours, or until 2 a. m. of Tuesday, without intermission, but with a slight diminution of intensity. This disturbance was apparently not due to an earthquake at some distant point in the Pacific Ocean, although such are frequently recorded on the gauge. Neither could it have been caused by a storm of short duration but great intensity, such as that which had a short time before passed over La Paz in Lower California. The present disturbance, consisting of about twenty-five large fluctuations, was in all probability due to some one of the greater hurricanes that last for many days. Such storms as they move onward continue growing up to a maximum stage of development, after which they break up or die away. The whole region of the ocean over which they pass is lashed by the winds into a terrible sea, whose waves, spreading out in all directions, are easily recorded on such gauges as that at Sausalito. It has been suggested that we have here a record of waves emanating from the hurricane encountered during the 15th, 16th, and 17th, by the steamship *Tacoma*, which left Yokohama on the 10th and arrived at Victoria, B. C., on the 27th. But that hurricane, which was southeast of Kamschatka on the 15–17th, must have been much nearer Japan and of much smaller extent on the 10th. Its track on this latter date was probably at a distance of about 70° or 75° of a great circle, or perhaps 5,000 statute miles west of San Francisco, and its waves would require twelve hours or more to reach Sausalito.

In the MONTHLY WEATHER REVIEW for May, 1877, pages 9 and 10, the present editor gave some data for determining the average velocity of very large waves across the Pacific Ocean, from which it appeared that the first great wave moved from an earthquake center on the coast of Peru to Honolulu, or through 96° of the great circle in fourteen hours, and therefore at the average hourly speed of 6.8°. This was much larger than the speed when passing over shallower portions along the coast of the Pacific. It was also larger than the speed of the succeeding waves, and especially of the maximum wave, which fact simply shows that the first waves, moving with greater speed, flattened out, and perhaps even disappeared, while the slower speed of the maximum wave was really the speed of a group of waves. When a group of waves runs along in smooth water under a calm the individual waves can be seen to be always, as it were, running forward through the group and dying out in front so that in deep water the speed of the group, as a whole, is about one-half that of its individual components, but in shallow water they may equal each other. In strong storm winds the same rule holds good. The average measured speed of large storm waves is given as follows at page 28 of the Navigator's Handbook for the Indian Ocean, published in German in 1892 by the Seewarte at Hamburg:

In the region of the trade winds the average length of the waves of the Indian Ocean is 96 meters (315 feet); the periodic time, 7.6 seconds; the rate of advance of the crest, 12.6 meters per second (28.2 miles per hour).

In the region of the strong west winds in the southerly part of the South Indian Ocean the average length of the waves is 114 meters (374 feet), the periodic time is 15.0 seconds, the rate of advance of the crest is 15.0 meters per second, or 33.6 miles per hour.

The size and speed of the waves stand in a rather complex relation to each other, but in general the longest waves go the fastest. The speeds of individual waves are greater than the progress of appreciable disturbances. As a wave proceeds outward and gradually diminishes in its amplitude as the distance from the center increases, it comes soon to a region where it may be said to have died away; but the successive arrival at this outer limit of the following stormwaves finally builds up an appreciable wave, and the limit of inappreciable disturbance is pushed farther beyond. In this way the circle of disturbance slowly spreads to a great distance over the ocean, but the rate of spreading is far slower than the rate of progress of the individual waves. The progress of the above-mentioned earthquake wave from Peru to Honolulu, at the rate of 6.8° per hour, is the rate peculiar to a very long and flat primary wave moving over very deep water, while the rate above given for the wind waves of the Southern Indian Ocean relates to a comparatively steep and short wave. The longest waves that have been measured during storms at sea are also given in the above-mentioned German publication as 830 meters (2,723 feet). Another long one was measured in the South Atlantic Ocean at 590 meters (1,936 feet). The highest waves that have been reliably measured are 11.5 meters (37.7 feet), in the Southern Indian Ocean, and in the same region waves of 7 meters (23 feet) high were measured by the *Challenger*. These heights are the vertical distances from the bottom of the trough to the top of the crest.

When very long and flat waves pass from the deep ocean water into shallower, they become shorter, steeper, and slower, and *vice versa*. The waves that sometimes pass as earthquake ocean waves very rapidly across the Pacific are of this character. The theoretical speed of such waves is but little less than that of the long, flat, tidal waves, and depends principally upon the depth of the water. The following figures for tidal waves are quoted from Lamb's Hydrodynamics, London, 1895, p. 274:

Ocean depth.	Velocity per hour.	
	Nautical miles.	Degrees of a. G. C.
Feet.		
1,250	120	2
5,000	240	4
11,250	360	6
20,000	480	8

In the tidal wave proper the motions of the individual particles of water are nearly horizontal, but in surface waves they are nearly vertical.

It is sufficient for our present purpose to say that the first wave observed at Sausalito must be tracked backward at the rate of about 6° or 7° per hour, if we wish to determine the time and place of its origin. A circle of 40° radius, or from 6.7 to 5.7 hours of time, would pass through the equator south of San Francisco as its center, or through Honolulu southwest of that center. This circle would not quite reach to Unalaska, but would extend beyond Sitka. It is quite likely that we have to seek for the origin of our hurricane or earthquake wave within this circle on November 10, rather than on the coast of Japan on November 9. In the southern quadrant of this region, namely, between the Sandwich Islands and the coast of Mexico, hurricanes of considerable violence occasionally occur, not to mention the ocean waves started by the earthquakes in the Sandwich Islands.

The weather map of November 11 shows a high area central over the Rocky Mountains, and a configuration of isobars such as would harmonize with the location of a storm center at about 30° N., 125° W. Vessels lying between this center and the Mexican coast would experience southerly winds, and as the storms move toward the northwest until they reach the thirtieth parallel, therefore vessels bound for San Francisco would gradually remove from the center, although still feeling the influence of the favorable winds.

A most important contribution to our knowledge of this class of storms (to which the La Paz hurricane also belongs) was published in the second volume of the narrative of the U. S. Expedition to Japan by Commodore Perry, and an abstract dated September 6, 1856, was published after the death of the author in the American Journal of Science and Art for July, 1857 (2), XXIV, pp. 21–38. This was the last work of W. C. Redfield, the pioneer in the study of the movements of hurricanes. It is entitled, On the Cyclones or Typhoons of the North Pacific Ocean, with a chart showing their courses of progression.

In the latter part of this memoir, which is dated December 26, 1856, Redfield gives the tracks of thirteen hurricanes which passed from about N. 12° between W. 95° and W. 115°, northwestward parallel to the coast of Mexico and Lower California during the season June–October, and in the years 1847–1855. Two other tracks are also given of storms that in attempting to recurve in about N. 20° ran into the Mexican highlands and were more or less modified thereby. Farther to the westward and apparently entirely across the Pacific Ocean, similar whirlwind storms frequently arise. These all move northwestward at first, and if they have not already died away, recurve at about N. 30°, and then move northeastward. As we go farther west these hurricanes are longer lived. The briefest are those that begin on the Mexican coast, but the longest lived are those that begin in the neighborhood of the Caroline Islands and move slowly to the west-northwest, until they recurve before striking Japan. These latter hurricanes may last from five to fifteen days before recurving, and nearly as much longer after doing so. The number of incipient cyclones, typhoons, or hurricanes is apparently quite large and uniformly distributed in a zone across the breadth of the Pacific between N. 5° and 15°, but the proportion of those that die out before becoming important hurricanes appears to increase as we approach the Mexican coast. A similar law is observed in the Atlantic Ocean and it must depend, at least in part, on the fact that the development and recurving of a hurricane is favored by the presence and underflow of cold, dry air on its northwestern side. The reason why so many should die away before recurving, especially in the region between the Sandwich Islands and America, seems to be that the underflow from the northwest consists of air that is both moist and warm, and therefore does not favor the formation of cloud and rain. If the waves recorded at Sausalito came from a hurricane of this class it must have been one of the rare cases of a storm moving northwestward near the Sandwich Islands and recurving to strike the coast of Alaska. The storms that occur very near the west coast of Mexico, as in the La Paz hurricane, are described in the following quotation from the Pilot Chart of the North Pacific Ocean for the month of March, 1896:

> The months of September and October, or the period during which the wet season on the coast of Lower California and Mexico is supplanted by the dry season, are noted in those regions for the occurrence of local storms of great violence, known by the name of "El Cordonazo de San Francisco," or the "Whip of St. Francis." These storms develop rapidly and are especially dangerous to vessels lying at anchor in open harbors and roadsteads. In the harbor of Mazatlan, September 20, 1888, the German bark *Parnass* was blown from her moorings and suffered serious damage.
>
> The approach of one of these storms is announced by a heavy southerly swell, a distinct rise of temperature, and light rains, which later become a torrential downpour. The fall of the barometer is at first slight, but afterward extremely rapid, a case being on record of a fall of six-tenths of an inch in forty minutes. The wind, setting in from the northeast with a force of 7 or 8, shifts later to the southeast and southwest, increasing in force to 10 or 11. The duration of the height of the storm varies from two to eight hours; its extent is ordinarily small. In the case of the *Parnass*, cited above, winds of ordinary force only were noted at places in the immediate neighborhood of Mazatlan,

and the captain of a steamer which reached that port September 21 reported a fresh southwest wind and a steady barometer during the hours at which the *Parnass*, not more than 50 miles distant, was battling with the full force of the hurricane.

Trustworthy reports of these storms are rare, and for this reason it is impossible to draw definite conclusions as to the direction and velocity of motion of the storm center. No reports of their occurrence south of the fifteenth parallel have thus far been received, although Captain Sewall, of the American ship *Paul Revere*, described an encounter with a storm of a similar nature, August 8, 1888, in N. 15°, W. 116°, the storm beginning on the evening of August 7, with the wind from the southeast and a heavy swell from southwest. In the vicinity of the mouth of the Gulf of California the path of the storm is, in general, northerly, following the line of the coast at some distance to seaward.

SUNSHINE.

The occurrence of 100 per cent in the column of duration of sunshine during the first morning hour often strikes the eye by contrast with the rare occurrence of the same high percentage at other hours of the day. This was especially the case in Table IV for October, 1895. As a rule, neither haze, fog, pallium, nor cirrus prevails in the dry American climates, but the principal cloud is the cumulus of midday. The early mornings at or before sunrise are cloudless, but as soon as the surface ground is heated by the sun and the topsy-turvy movements of the daytime begin there begins a steadily increasing amount of cloudiness. It may thus happen, for instance, that if the total duration of sunshine before 6 a. m. is only a few minutes at any station, all of it will be clear sky, whereas if the sunshine had lasted for nearly the whole hour, as it does between six and seven, then the percentage would have dropped lower.

DROUGHT AND AGRICULTURE.

The recent long-continued drought has stimulated the consideration of the question whether there is any permanent change in the quantity of water held in the lakes, both large and small, that cover our so-called Lake Region. It is stated with some show of credibility that during the past ten years there has been a very appreciable drying up of the smaller lakes in Minnesota, and that cultivated fields now occupy the rich lake bottoms that were formerly covered with from 10 to 20 feet of water. The St. Paul Pioneer Press publishes letters from a large number of correspondents representing the whole area of the State, showing that the larger lakes have diminished in volume and the smaller ones have often dried up entirely. A similar story comes from South Dakota. The average rainfall of the past ten years may have been slightly below the normal in these States, but not to a sufficient extent to justify us in attributing this change in the lakes to any great meteorological or climatological change. The fundamental reason for the drying up of the lakes is to be found in the cultivation of the soil and the artificial changes in the drainage. Every acre of virgin soil that is plowed up and cultivated begins to evaporate into the air the moisture that it formerly conserved. Similarly every new drain that is dug helps the water that formerly stayed in the soil to flow off into the rivers. The progress of agriculture begins by an effort to drain the rich lowlands that are usually too wet and ends by the necessity of artificially watering both the dry uplands as well as the warm lowlands. In other words, we begin by evaporating and draining off the water that we eventually wish we could get back again. Successful agriculture involves a steady progress toward the need of more water and the wisest way of using it, but the atmosphere presents an irregular succession of dry years and wet years, and agricultural methods must vary to suit the seasons. In the words of the Pioneer Press:

> Of the seven thousand lakes that dotted Minnesota in 1885 perhaps a third of them will permanently disappear as a result of the cultivation of the soil, the remainder will fluctuate in volume with the average rainfall, shrinking materially during successive dry seasons and reappearing in all their ancient beauty when the rain comes back to fill their empty bowls.

The above considerations emphasize what we have often said about the importance of long-range predictions as to the character of the coming seasons. The same idea is emphasized in the following quotation from the Sioux City Journal:

> What really is needed is a better understanding of the conditions that bring about our seasons—our periods of prolonged drought and our periods of continuous wet weather. We want meteorology made plainer, to the end that farmers may be better prepared for meeting unfavorable conditions. We want a better understanding of causes and effects, and then a better understanding of the way to take care of all the moisture we have or to get rid of what moisture we do not want. It has been demonstrated that a dry season is good for crops, for the season just closed was a good crop season. The science of agriculture is one that will repay careful study. It is worthy of the best thought of the day, and meteorology ought to supplement agriculture to the great benefit of the latter.

CHINOOK IN MONTANA.

According to R. M. Crawford in the Monthly meteorological summary of the Montana Weather Service the Observer, C. L. Herzog, at Great Falls in that State (N. 47° 28′, W. 111° 20′) states that—

> A peculiar phenomenon was closely observed there on the 16th inst. A cold-wave signal having been ordered for that date, the weather at time of receipt of order was very warm and pleasant, and the observer decided to pay more than ordinary attention to the expected change. About 3.30 p. m. the wind which had been blowing gently from the north, veering at times to the northeast, with a velocity of about 9 miles an hour, stiffened quickly and coming directly from the north lowered the temperature 6° in less than five minutes. The indications were that the temperature would fall much lower, but suddenly dark vaporous looking clouds appeared in the extreme southwest, with them simultaneously came a strong gale from the same quarter, blowing at the rate of at least 40 miles an hour. The southwest gale seemed to meet the wind coming in from the north and drove it in a whirl directly toward the northeast across the prairie in a funnel-shaped cone, plainly perceptible for a long distance by the dust gathered. The temperature quickly rose to 58°, the maximum recorded for this date, and the chinook had mastered the cold wave.

[NOTE.—Great Falls is on the Missouri River about 30 miles above Fort Benton, and 60 miles in a straight line, or 150 miles by the river, northeast of Helena. To the north and west are the elevated prairie lands, famous grazing pasture and the last retreat of the almost extinct bison. To the south and west the hills rapidly increase and become the Rocky Mountains. The contour line of 5,000 feet elevation lies about 20 miles to the south, but about 60 miles to the west. Great Falls itself is on the 3,000 foot contour line which crosses the Missouri at this place and extends down the river valley, and but a short distance from it, for 200 miles. On the 15th and 16th an area of high pressure, 30.6, covered Oregon and northern California and extended southeastward into Utah, while low pressure prevailed in Alberta. The cold north and northwest winds on the southwest side of the low were probably felt not only in Alberta but southward and up to an altitude of 3,000 feet. But any air that was pushed into the low pressure from the high area in Oregon and Idaho must necessarily descend through the lowest gap in the Rocky Mountains, which is about 50 miles southwest of Great Falls, and therefore from an altitude of at least 6,000 feet. Through this, and similar gaps farther northwest which are not so low, a descending current always flows over western Montana when the general distribution of pressure is as above described, and warm chinooks extend down to some level such as that of 3,000 feet. There the mixture with the cold northerly winds from Alberta and Saskatchewan begins, and sometimes for several days the border line between warm and cold sways to and fro. Observers in this region have an opportunity to observe several interesting phenomena such as the mixture of the two winds and the character of the clouds formed thereby, or the remarkable connection between temperature and pressure. At one time rising pressure means warmer